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DEPENDENCE OF THE SPECTRAL RELATION OF DOUBLE STARS
UPON DISTANCE

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In the course of an investigation of the cause of the spectral differences of the stars, an examination of the spectra of the components of double stars was made. Almost at once it was seen that there was a relation other than the well known conclusion that in contrasted pairs the fainter component is generally of the earlier type. It was found that such stars are almost invariably very distant, and that the reverse generally occurs in the near pairs.

The principal data used in this investigation were taken from the observations of the spectra of 745 double stars made at Harvard and classified by Miss Cannon.¹ Seventy-eight stars were selected of which the spectra of both components had been determined, having a difference of brightness of at least half a magnitude and known to be either binary or to have common proper motion.

It was noticed that the stars in which the fainter component was of the earlier type were, in general, closer together than those in which the companion was of a later type. The effect of distance on the separations of these stars was investigated by means of proper motion. The result indicated a greater average absolute separation in both classes than for the stars whose magnitudes and spectral classes are nearly the same. Incidentally, however, it was shown that the pairs in which the fainter component is of earlier type are distant, whereas those in which the fainter companion is of later type, with the exception of the stars both of whose components are of classes B and A, are much nearer.

Of the stars selected, 24 have the fainter components of the same spectral type, 26 have the fainter components of later and 28 of earlier spectral type. The last two groups are given in detail in the tables following.

With the exception of the pairs (12 in number) of table 1, which have *both components of classes B and A* and whose proper motions are less than $0''.05$, the remainder show large differences of spectral type and large average proper motion. It is to be noted that 4 of the 12 stars with small μ in this table, having the fainter component of *later* type, belong to 15 Cephei. The consistency in the spectral relations of this group is noticeable.

The pairs of table 2, with two exceptions, show small proper motions. The proper motions of these two stars cannot be said to be large and it is further to be noted that their differences of spectral type are rather small. The

¹ *Ann. Harvard Coll. Obs., Cambridge*, 56, no. 7.

average μ of the entire 28 stars is but $0''.037$, or omitting the largest two, is but $0''.030$. The criterion of proper motion, therefore, indicates that these stars are at the same general distance as the class B stars.

The stars of table 2 also show a decided preference for the galaxy, half of them being within 15° and three-quarters of them within 40° of the galactic plane. This is significant when it is considered that the principal stars of these pairs belong almost entirely to the middle and later types of spectra.

TABLE 1
FAINTER COMPONENT OF LATER TYPE

MAGNITUDE BRIGHTER COMPONENT	Δ MAGNITUDE	SPECTRAL CLASS		μ	s
		Brighter	Fainter		
5.6	0.9	A ₅	G ₅	0".143	23".7
5.2	2.6	F ₅	G	.295	49.4
6.0	0.7	A ₀	A ₂	25	16.6
3.0	3.3	B ₃	A ₀	52	117.3
4.9	0.6	B ₃	A ₀	82	7.8
1.3	6.3	B ₃	G	.247	176.7
5.3	1.8	F ₀	G ₀	.289	288.1
5.4	1.4	A ₀ P	A ₃	29	145.3
0.3	1.4	G ₀	K ₅	3.67	21.9
2.9	2.2	A ₂	F ₅	.131	231.0
4.5	2.2	F ₀	K ₀	.169	108.3
4.3	2.2	B ₃	A	34	41.3
4.9	2.7	A ₂	F	65	88.8
6.0	0.6	B ₃	A	38	21.7
5.8	0.8	B ₃	A	22	35.7
4.6	1.9	A ₃	G?	.230	6.9
5.8	0.7	B ₃	B ₅	18	22.4
3.6	2.5	A ₅	K ₀	.107	337.1
4.8	2.7	B ₅	A	10	22.8
Var. 3.4	4.4	B ₂	B ₃	8	46.0
{	6.7	B ₀	B ₉	13	183.4
	6.8	B ₅	B ₉	13	136.1
	6.7	B ₀	B ₅	13	236.3
	6.8	B ₅	B ₉	13	192.4
4.2	1.7	B ₉	A ₀	.121	26.9
4.8	4.8	Ap	K	.138	222.8

Further evidence is found in 19 of the Harvard stars which have composite spectra and in 62 stars of Campbell's Catalog of Spectroscopic Binaries,² in which the spectra of both components have been observed or strongly suspected.

For both spectra to appear on a photograph, the difference in brightness of the components of close binary stars will usually be small. On account of the tendency for components of nearly the same brightness to have similar

² *Lick. Obs. Bull., Berkeley*, 6, 1910, (46).

spectra, the evidence from these two sources is not of as great weight as the preceding. It is, nevertheless, quite definite.

Of the 19 Harvard composite stars, two are somewhat uncertain as to the difference of spectral class, both being of early type. Of the remainder, the one having the largest proper motion (0".15) has the fainter component of the later type. The remaining 16 all have very small proper motions. Of these, 5 have the fainter component of later type and 11 of earlier type. All of

TABLE 2
FAINTER COMPONENT OF EARLIER TYPE

MAGNITUDE BRIGHTER COMPONENT	Δ MAGNITUDE	SPECTRAL CLASS		μ	s
		Brighter	Fainter		
6.2	1.2	G ₀	A	0'.018	2'.9
4.3	0.9	A ₃	A	42	2.6
2.3	2.8	K ₀	A	70	10.7
5.0	1.4	G ₅	B?	34	6.9
5.5	1.2	G	A ₃	29	3.0
5.9	1.1	A ₀	B ₉	27	28.9
5.8	1.2	G	A	47	0.4
5.4	3.1	K	A	7	2.3
3.9	1.9	K ₀	G	97	13.3
6.4	0.5	G	A ₂	41	63.4
4.2	2.4	G ₅	A ₂	54	30.6
5.2	1.5	K ₀	A ₃	17	20.6
5.3	0.5	A ₂	A	33	21.6
2.7	2.4	K ₀	A	49	2.8
3.5	4.5	K ₀	G ₀	155	104.8
1.2	5.8	Ma	A	34	3.2
6.4	1.1	K	F ₅	48	111.2
6.1	1.7	G	A	11	45.5
5.6	1.2	F ₅	A	13	0.6
7.1	1.0	G	A	42	4.1
6.0	1.5	F ₅	A ₂	18	15.0
3.2	2.1	K	B ₉	9	34.7
5.6	3.3	K ₀	A	34	19.8
6.5	1.1	F	A	Small	1.2
5.7	2.2	G ₀	A	20	89.9
6.1	0.	G ₅	A ₂	25	23.0
3.9	3.2	K	B ₃	2	107.1
3.3	2.8	G ₀	A ₀	28	205.2

the most strongly marked spectral contrasts have the fainter components of earlier type and all but one of these 11 are well marked in respect to spectral contrasts.

Of the 62 stars of Campbell's Catalog, 30 belong to types O and B and 23 to type A. It is reasonably certain, therefore, that all of the O and B stars are distant and the probability is strong that most of the 23 stars of type A

are distant also. Campbell concludes,³ I understand, that the rule that when one spectrum is considerably fainter than the other, the spectrum of the secondary is apparently of a slightly earlier type than the spectrum of the primary, applies to these stars, which we have just found to be distant.

Both of these pieces of evidence are confirmatory of the condition previously found.

I have also examined several well known systems whose colors have been observed, viz., α Herculis, η Geminorum, γ Delphini, η Cassiopaeiae, ξ Boötis, β Cephei and γ Leonis. These stars also show in general the same relation to distance.

Careful consideration of the data seems to show beyond doubt that the relation is to distance coupled with low galactic latitude. It cannot well depend upon the actual separations of the stars, for the ranges in that respect seem to be about the same in all of the groups. It can scarcely depend upon the differences of mass of the components as indicated by their differences of brightness, for a similar reason. There is a difference of absolute magnitude between the two groups, but there seems to be no reason for suspecting a relation in this case, whatever may be the bearing of such differences in others.

It is not known whether both components of double stars were originally of the same spectral type or not. Investigators have generally assumed that they were. It is not possible to say, therefore, just what the course of change has been. However, we may justly conclude, I think, that the conditions are such in these regions as to produce *opposite* spectral effects in the components. There can be little doubt that the fainter components are in general also of smaller mass. The conclusion may be stated, therefore, in the following form:—The conditions appear to be such that if two stars of unequal mass were introduced into the near region the smaller body would move more rapidly toward the later stage than the larger one, whereas in the relatively distant galactic regions the tendency would be for the smaller body to become of *earlier* type more rapidly than the larger one.

This investigation also shows that the greatest differences in spectral type are in general found among the stars whose components show the greatest differences in brightness. The differences of brightness in the pairs having the same spectra are consistently small for all types.

The results of this investigation seem to indicate with considerable force that some external cause is operating in more or less definite regions of our stellar system upon the conditions which produce spectral class.

The details have been given more fully in a paper which will be published in the *Astrophysical Journal*.

³ *Ibid.*, 6, 1910, (47).